An evidence review of face masks against COVID-19

Howard J et al. Proceedings of the National Academy of Sciences, USA, January 11, 2021, by 19 authors from the following institutions:

Data Institute, UCSF; Alpert School of Medicine, Brown University; Center for Quantitative Biology, Peking University; School of Information, UNC; Institute of Chemical Process Fundamentals, Czech Academy of Sciences; Dept. of Primary Health Care Sciences, Oxford University; TB Proof, Cape Town and Media Lab, Stanford University School of Medicine; Dept. of Aeronautics and Astronautics, MIT; Dept. of Physics, Hing Kong Baptist University; Complex Systems Division, Beijing Computational Science Research Center; Dept. of Information Systems, Business Statistics and Operations Management, Hong Kong University of Science and Technology; Dept of Biostatistics, Fielding School of Public Health, UCLA; Perelman School of Medicine, UPenn; Data Umbrella, NY; Teacher Education Department, Vrije Universiteit Brussel; Open AI, San Francisco; Dept of Epidemiology, Fielding School of Public Health, UCLA

Decisions to implement public health policies are occurring in complex decision-making environments: COVID-19 is a novel virus about which new research is generated daily; genetic mutations of the original virus have led to new variants with characteristics different from those of the original virus; growth in new cases, hospitalizations and deaths has been exponential; and the discussion about policy measures has become politicized.

Background

Masks have been recommended for use in respiratory epidemics since the 14th century and were used successfully to control the 1910 Manchurian Plague.

Direct evidence for efficacy of public mask wearing

Evidence for the efficacy of public mask wearing is best provided by randomized controlled clinical trials (RCTs), a metaanalysis (summary) of trials to date, or by a systematic review of unbiased observational studies (studies where groups of people with some feature, such as mask-wearing, can be observed and compared with a similar group that does not have that feature).

Direct epidemiological evidence of mask use for COVID-19

- RCTs, where one group is assigned masks and another group is not, are unethical to conduct in a pandemic and for that reason there is no RCT for the impact of masks on community

transmission of any respiratory infection in a pandemic. Because there is only one RCT there is no metaanalysis.

- One observational study found that face masks were 79% effective in preventing transmission within the household if they were used by all members of the household before symptoms appeared.
- A systematic review by the World Health Organization reviewed two studies of mask use for their effectiveness on the SARS 2002-2004 pandemic (not SARS-CoV-2) outside health care settings. One study found no infections but the number of people involved was too small to be meaningful, and the other found masks were strongly protective for people wearing the masks, but did not look at transmission of virus to others.
- One controlled trial of mask use for influenza found that they were 80% effective for the wearer.

The authors concluded: These few studies taken together, while they studied other respiratory viruses, indicate that masks are 70-80% effective at preventing illness for the person wearing the mask. These studies are informative but not compelling on their own.

Reviews and RCTs of mask use for other respiratory illnesses (influenza, others)

- A Cochrane review of 67 RCTs and observational studies found that among all physical interventions (social distancing, hand hygiene) overall, masks were the best performing intervention across all populations, settings and threats. A preprint review of this article concluded that where masks alone were studied, there was insufficient evidence to provide a recommendation on their use without other measures.
- A study evaluating masks as protective intervention for the community, health care workers and as source control concluded that community mask wearing by well people could be beneficial especially for COVID-19, where transmission can occur prior to symptoms.
- A study by the Usher Institute that used laboratory and epidemiological evidence concluded that homemade masks worn by sick people can reduce virus transmission.
- A preprint systematic review of epidemiological, theoretical, experimental and clinical evidence concluded that face masks in a general population offered significant benefit for preventing the spread of respiratory viruses, but their utility is limited by inconsistent adherence to mask usage.
- A second preprint systematic review of RCTs concluded that there was weak evidence for a small effect from mask use in the community but the studies often had serious limitations (too few people for robust statistical analysis, poor compliance by mask wearers, poorly designed control groups).
- RCTs of the impact of wearing masks on transmission in households suggest that transmission can be reduced by using face masks and hand hygiene, and that concerns about acceptability and tolerability should not be a reason against their recommendation.
- A RCT of face masks and hand hygiene seemed to prevent household transmission when implemented within 36 hours of symptom onset in the index patient (first person infected), and a RCT of face masks and hand hygiene suggested that they may reduce illness in shared living settings.

- A RCT found that face masks and hand hygiene may reduce the rate of influenza-like illness and confirmed influenza in community settings during influenza outbreaks.

The authors concluded: Overall, the combined use of masks and hand hygiene are important for mitigation of pandemic and interpandemic influenza. This evidence supports the efficacy of mask use for COVID-19 but is inconclusive by itself.

Evidence other than RCTs that should be considered

RCTs (cited above) are best suited to medical interventions where a treatment effect can be measured at the individual, rather than the population level and the findings apply to the target population as defined by characteristics of the people enrolled in the clinical trial. In those cases, masks function as Personal Protective Equipment (PPE) because they protect the individual. For public health decisions that affect a population, we are concerned with the aggregate impact of individual-level interventions on the whole community, and we must consider a wider body of evidence to evaluate the risks and benefits of the intervention and use that analysis to inform policy decisions. A principle that is used in public health is the precautionary principle, which states that "*when human activities may lead to morally unacceptable harm that is scientifically plausible but uncertain, actions shall be taken to avoid or reduce that harm*." Potential harms from COVID-19 include illness, hospitalization, death and economic impact.

The evidence following has bearing on the decision that will be taken by the Uxbridge Board of Health.

Population impact

Ecological studies
- Two studies using multiple regression analysis found that transmission was 7.5 times higher in countries that did not have a mask mandate or universal mask use compared to those that did.
- The daily growth in cases was 2% lower in states with mask mandates than in those without, and this was estimated to prevent 230,000-450,000 cases.
- In comparisons of US and other international regions, face masks were estimated to reduce infections and fatalities by a large measure; a nationwide mask mandate was estimated to have a one trillion USD impact on GDP.
- The marginal benefit per cloth mask worn was estimated to be US $3,000-$6,000.
- COVID-19 clusters in recreational "mask-off" settings are significantly more common than in "mask-on" settings.

Modeling
R_0, the basic reproduction number of the virus, is the average number of people infected by one person in a susceptible population with no interventions. The goal of public health policies is to reduce R_0 to less than 1 (meaning that each infected individual transmits the virus to fewer than one person, leading to elimination of the virus in the population over time). R_e is the average number of people infected by one

person in a population where policies and other measures are in practice. The R_0 for the original COVID-10 virus and the delta variant is 2.4-3.9; for the omicron variant it's estimated to be ~10.0. With a policy where all individuals must wear a mask all the time, a median effective R_e of less than 1 can be reached even if masks are less than 100% effective.

- When at least 80% of a population wears masks, there is a significant reduction in R_0, leading to eventual elimination of the disease; impact is minimal when only 50% of the population wears a mask.
- A study that combined mask wearing and mask efficacy found that the reduction in R_0 is highest when a greater proportion of the population wears one and masks worn are efficacious (trap viral particles inside the mask); the effects are larger the higher the R_0 (as with the Omicron variant). With 50% mask usage and 50% efficacy, 100 cases at the beginning of a month become 584 cases at the end compared to 31,280 cases when masks are not used. This helps to protect the health care system.
- High use of face masks in public could lead to COVID-19 elimination, and combining face masks and social distancing is more effective for control than either measure alone.
- Use of N95 respirators among 80% of a population eliminates influenza transmission.
- Masks, even those with suboptimal efficacy for preventing disease to the wearer and transmission to others could substantially decrease R_e.

The authors concluded: Overall, population-level studies of the impact of wearing masks are consistent with models that find that wearing masks can lead to substantial population-level impacts on virus transmission.

Transmission Characteristics

Persons with COVID-19 are typically infectious from 2-15 days prior to developing symptoms, with a median length of 5.1 days, and they may be most infectious when symptoms are mildest or not present. High viral titers are reported in the saliva of patients and are similar in children and adults, and this supports mask-wearing by everyone, children and adults. Policy interventions must address transmission due to people who are infectious but asymptomatic.

Respiratory particles can remain suspended in air for many minutes and can accumulate depending on air currents and ventilation status of the environment. These particles are produced when people breathe, speak and when they cough or sneeze (ballistic trajectories). The longer respiratory particles are suspended in the air, the smaller they become due to evaporation of water content. A recent analysis found that normal speaking may be a key factor in virus transmission, particularly when people speak loudly or for a long period of time. Respiratory particles can stay airborne long enough for people to inhale them. Particles smaller than 5 microns [COVID-19 original virus and Delta variant particles are 0.125 microns in size; putting this in perspective, a strain of human hair is 700 times thicker than this] can reach into the lower airways and alveoli of the lungs, whereas larger particles are deposited in the trachea and larger intrathoracic airways.

The authors concluded: Smaller floating respiratory particles with virus are more challenging to filter than are larger particles with momentum, such as are generated by coughing and sneezing. Masks keep persons who are infectious from spreading virus when they speak, cough or sneeze, since the respiratory particles are larger at the source. As these particles circulate, they become smaller, and masks may be less effective at preventing infection among susceptible people.

Masks for source control (mask-wearing by potentially infectious people)

Human studies: Infectious particles

- There are no studies that have measured the impact of any kind of mask on the amount of COVID-19 particles from human actions (speaking, coughing, breathing, sneezing).
- One study found that surgical masks were effective at blocking seasonal coronavirus particles of all sizes for all subjects, but less effective at blocking rhinovirus particles or smaller influenza particles. This suggests masks may have a significant role in source control for the current outbreak.
- In studies done from 1962-1975, investigators found that unmasked subjects expelled more than 5,000 contaminants/5 ft^3 during talking, and 7.2% of them were associated with particles smaller than 4 microns in diameter. Cloth masked subjects expelled an average of 19 contaminants/5 ft^3, of which 63% were less than 4 microns in diameter. Overall, masks filtered more than 99% of contaminants. Other masks studied filtered more than 97% of contaminants.
- Influenza was detected on sample plates at 20cm from 7/9 coughing patients not wearing masks but in no patients when they were wearing masks.
- Surgical masks produced a 3.4-fold reduction in viral copies in exhaled breath by influenza patients.
- Among six patients with cystic fibrosis infected with *P. aeruginosa*, airborne load (a mix of all the air around a patient) was reduced by 88% when wearing a mask compared to no mask. These results were confirmed by two other studies.
- Surgical masks filter 96% of 1 micron diameter particles compared to 58-94% of masks made with generally available household materials.

Human studies: Aerosol and droplet filtration

- Using Schlieren imaging, all kinds of masks were found to limit the spread of an emission cloud caused by speaking, coughing, and sneezing. This finding was consistent with a fluid dynamic simulation that estimated the filtration level at 90%.

A potential benefit of masks as source control is that they may reduce surface contamination, although this is not known to be a major source of COVID-19 transmission.

The authors concluded: In summary, there is laboratory-based evidence that household masks have filtration capacity in the relevant particle size range, they block aerosols and droplets from the wearer and help people keep their emissions to themselves.

Masks for PPE (protection for potentially susceptible wearers from infection)

Simulations must be used because it is unethical to challenge a person with infectious particles to see if a mask is protective.

The efficacy of a mask is affected by the material it's made of and the overall fit of the mask. NIOSH-approved N95 masks filter at least 95% of very small particles (less than 0.3 microns in diameter) at flow rates of 85L/minute, simulating a high work rate and far higher than at rest or low-intensity breathing (so, "worst-case").

- Using 0.078-micron particles, there was more than 90% penetration for all cotton masks and handkerchiefs, with 50-60% penetration for surgical masks.
- Cotton, polyester and polypropylene multilayered structures can meet or exceed the efficiency of materials used in some medical face masks, depending on the materials and how they are treated.
- Among masks made with common cloth fabrics, efficacy varied from 12-99.9% at flow rates lower than at-rest respiration. Many materials had greater than 96% filtration efficacy for particles greater than 0.3 microns, including 600 threads/inch cotton, cotton quilt, and cotton layered with chiffon, silk or flannel. A combination of materials is more effective than any one alone.
- Fitted masks of any type offer more protection than unfitted masks.

All types of masks are at least somewhat effective at protecting the wearer because they reduce aerosol exposure, are relatively stable over time, and are unaffected by duration of wear or type of activity. For these reasons, any type of general mask use is likely to decrease viral exposure and infection risk on a population level even if they don't fit perfectly.

Masks as PPE do not allow hands to directly touch the nose and mouth which may be a transmission factor.

Overall, cloth face covers can provide good fit and filtration for PPE in some community contexts, but efficacy varies depending on material and design, the way they are used, and the setting in which they are used.

Sociological considerations

Risk compensation behavior
Mask-wearing may lead people to neglect other measures such as physical distancing and hand hygiene, but this has not been significant at a population level. Polling and other data have shown mask wearing to be positively correlated with adoption of other preventative measures.

The authors conclude: If masks are mandated or strongly recommended this should be accompanied with messaging that also emphasizes other preventative measures.

Managing the stigma associated with wearing a mask
People with certain illnesses (tuberculosis) or people of certain races may feel they are stigmatized when wearing masks. For that reason, requiring only sick people to wear masks is not a good policy and mask-wearing should be universal if required.

Creating new symbolism around wearing a mask
Masks can serve as a reminder of the pandemic and can encourage others to wear masks and to adopt other preventative behaviors.

Implementation considerations

Supply chain management of N95 Respirators and surgical masks
When in short supply N95 respirators and surgical masks should be limited to health care workers.

Mandatory mask wearing
Whether or not a person wears a mask is informed by her/his perception of personal risk.

- A pre-registered experiment in Germany with 925 people showed that a voluntary policy that would likely lead to insufficient compliance would be perceived as less fair, and could intensity stigmatization. The authors concluded that "A mandatory policy appears to be an effective, fair and socially responsible solution to curb transmission of airborne viruses."
- Modeling suggests that population-level compliance of 70% combined with contact tracing would be critical to halting epidemic growth. Population-level analysis suggests that laws and regulations are effective at increasing compliance and slowing the spread of COVID-19.

Decreasing transmission will also likely decrease the risk that novel variants, perhaps of even greater concern, could develop.

Conclusion
This review offers evidence in favor of widespread ask use as source control to reduce community transmission. Nonmedical masks use materials that obstruct particles of the necessary size and have been effective in reducing transmission of respiratory viruses, particularly when people are most infectious but may be asymptomatic.

Where mask usage has been required or widespread, community transmission has been lower.

Near-universal adoption of nonmedical masks when in public, combined with complementary public health measures, could reduce R_0 to below 1, thereby reducing community spread if such measures are sustained.

Modeling suggests that public mask wearing is most effective at reducing virus transmission when compliance is high.

The authors conclude: Mask use requirements should be implemented by governments or when not possible, by organizations that provide public-facing services. These requirements should be accompanied by measures to assure access to masks. Public health authorities should also provide clear guidelines for the production, use and sanitization or reuse of face masks.

When used in conjunction with widespread testing, contact tracing, quarantining of infected people, hand washing and physical distancing, face masks are a valuable tool to reduce community transmission.